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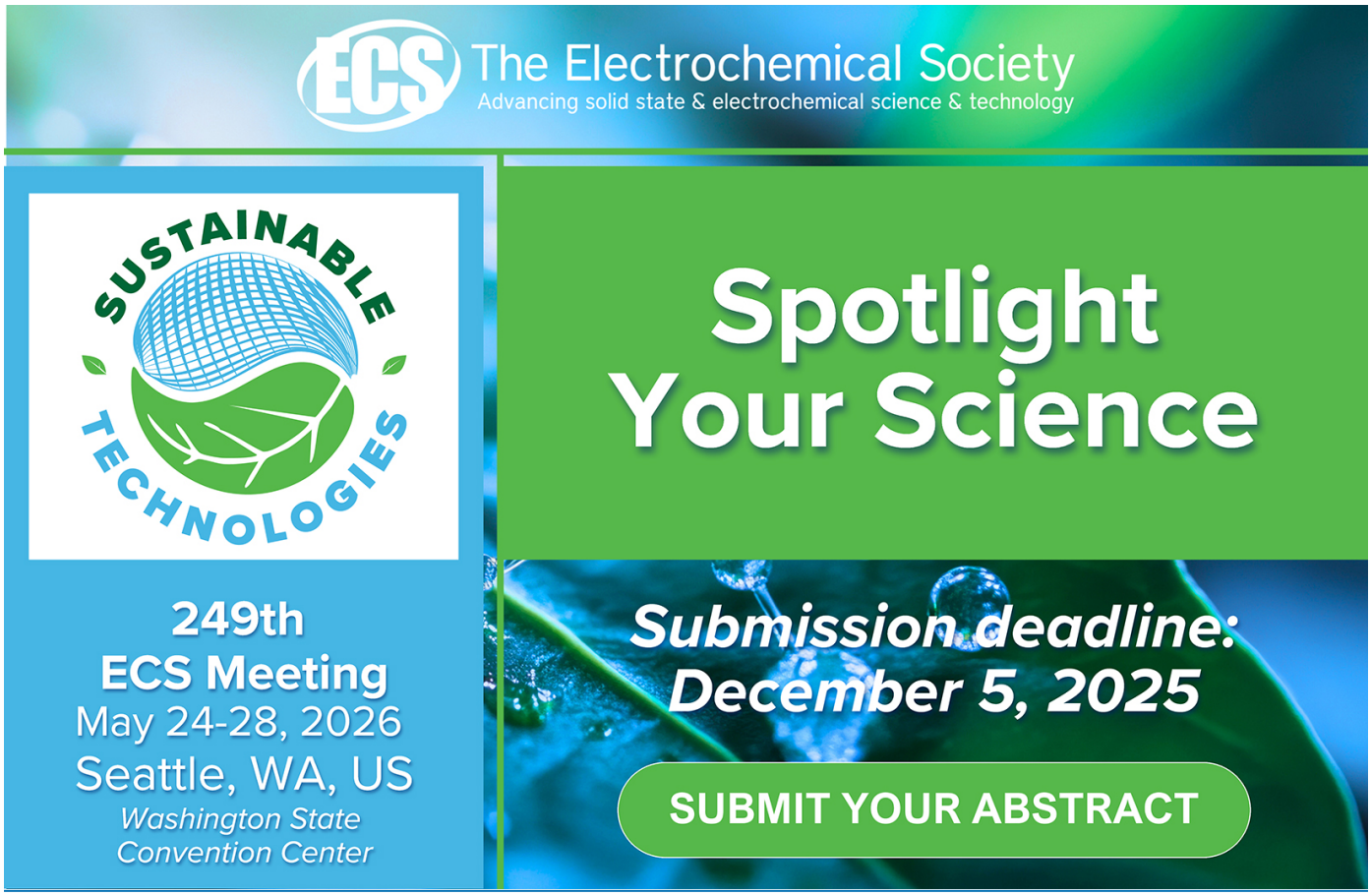
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Experimental determination of thermal conductivity as physical property of organic and recyclable materials

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Abstract. There are different types of traditional materials for insulation in different processes such as: clay, limestone, ceramic foams, among others, used mainly in furnaces and buildings, whose function is to reduce heat and acoustic noise transfer through the structure on which they are installed. Alternatives for insulation with reusable and organic materials are currently being sought. In this work, the physical property of the thermal conductivity of materials such as quartz, glass, bone, and coconut shells were analyzed in order to compare their thermal conductivity measured experimentally with respect to that reported theoretically, and determine if they are suitable for use in the market and also to have a foundation that allows subsequent processes to mix them, giving way to new insulating or refractory materials with better physical properties.

1. Introduction

The different materials under study were analyzed by X-ray diffraction (XRD) [1]. The results indicate that the sands are composed mainly of quartz, forming mature sands or quartz-sandites, their origin is related to the physical-mechanical disintegration of the rocks. In addition, the wettability of quartz correlates with the density of the non-aqueous fluid, *e.g.* oil, CO2, N2, etc., which may be in liquid, gaseous, or supercritical form [2]. Also found that quartz grains in many geological environments have low sensitivity to spectroscopic methods of analysis, resulting in weak signals to young samples [3].

On the other hand [4], seek to study different materials. They found that foam glass can be created by recycling waste glass obtained in urban areas of Russia, thus having some properties such as non-combustibility, water resistance, durability, ease of installation, among others.

These glass foams are produced in the form of plates, blocks, sheets, crushed stones, and pellets of different sizes. Therefore, it is concluded that the production of glass foam from waste glass will solve both the problem of increasing the energy efficiency of buildings and the problem of recycling urban glass waste [4]. Glass foam has also been developed from waste slag from thermal power plants, which serves as an ecological thermal insulator. The developed material has an almost unlimited service life at a cost 2-3 times lower compared to market counterparts. The application of this material makes possible to solve a series of environmental problems, such as energy saving and improvement of the environmental situation through industrial waste management.

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In the document of [5], tests were carried out on one of the components of the bone (calcium). The results were unfavorable for the researchers because calcium failed to react with the rest of the ingredients in order to reach the expected results. According to their conclusions, all this happened due to the high temperature that this type of elements withstands in a powdered state, which is a significant advantage for our research [6]. Discusses the size to which certain materials must be taken in order to produce adequate behavior in the thermal industry. It is said that they must be taken up to a very tiny particle size in order to be able to add them to the matrix and subsequently achieve a homogeneous mixture.

In 2014, coconut shells were used with concrete to make house beams and compare them with conventional beams, in which the torsional behavior of coconut shell concrete is comparable to that of conventional concrete. The specimens of coconut shell concrete have more ductility. The crack width for conventional concrete and that of coconut shell with the corresponding reinforcement ratios is almost similar. The results and performance of this research encourage the use of coconut shell as an aggregate for the replacement of conventional construction aggregate in beam elements that are subjected to torsion [7].

The manufacturing industry is constantly evolving thanks to the connection it has made with different engineering sectors such as electronics, computing, science, biology, mechanics, and other important sectors for the development of new technologies. At the same time, the techniques involved in the process such as inputs, lubricants, tools, and insulators must be improved. The latter is noteworthy due to the diversity in terms of tests and mixtures that can be performed to try to find new materials that allow innovating within the industry. You can find materials on the market which are attributed physical, chemical and mechanical properties of each one, in this case there will be an approach that goes towards the study of an important physical property such as thermal conductivity, which indicates If a material is an insulator or a conductor of temperature, and is highly dependent on its components, this study of temperature transfer of a material is done by measuring the ability to resist or conduct heat.

In which sector where there is heat and movement, is it not necessary to have an insulator? From this question we can start to observe that the need still exists, it is not completely satisfied. It is in this moment where there is a diversity of materials to be studied to find the best behaviors among them, which can give the guideline to later combinations to improve thermal conditions and to be presented as insulating materials that make their contribution to the environment in terms of recycling and reuse.

2. Materials and methods

In the development of this proposal, recycled materials will be used, both organic and inorganic, including quartz, glass, bones, and coconut shells. The thermal conductivities of these materials will be found in a pulverized state, which will be recorded by means of a thermal conductivity test bench for granular materials.

The thermal conductivity test bench is designed to apply the thermal conductivity formula, which gives us an intensive magnitude, which means that it does not depend on the mass or the size of the body. According to the result, it can be said whether the material placed on the test bench is insulating if its value is less than 0.100 or conductive if its value is greater than 0.100, henceforth the higher the value, the more conductive the material is, the thermal conductivity depends on the calorie flow of the temperature gradient that are physical properties that we will determine within the investigation. The characteristics of each of the materials to be worked on are explained below.

2.1. Quartz

Quartz is a silicate, which is present in a wide variety of geological conditions. It is found in many igneous and metamorphic rocks. Among the minerals, quartz is the closest to a pure chemical compound and has constant physical properties. The chemical composition of quartz corresponds to a mineral of high purity for its unique content of SiO_2, which meets the requirements of industrial quality such as glassware, optical components, electronics, and as a raw material for obtaining fused silica. according to the Mexican standard, which specifies the procedure for determining the properties of barite used in

drilling fluids, is adapted to determine quartz moisture [8]. Quartz is used for the production of cements, ceramics and glass. On the other hand, this compound has desiccant properties, that is to say, it has the capacity to remove moisture from the places where it is found, it is common to find, in the boxes of new electronic devices, some sachets containing silicon oxide, to avoid moisture. The manufacture of tablets and capsules in the pharmaceutical industry has silicon oxide as one of the main components within excipients. This product varies according to how its components are combined and from there derive its various uses such as industrial and medical uses, including the production of cosmetics [9].

2.2. Glass

Glass is a rigid, but not crystalline, transparent substance that appears when alkalies, lime, and sand or silica are mixed and then melted. Glasses that are usually made with lead are delayed. The melted and slowly cooled mixture becomes more viscous until it reaches the solid state, making it very clear if it is made of transparent materials. If the mixture is cooled abruptly the silicates can crystallize obtaining as a result an opaque brittle alloy, which is not glass. For these events, a slow cooling or tempering has to be performed, which is done in a specific furnace designed for this purpose. There is no fixed melting point for glass, but it is around 1000 °C. Most of the glass in the ancient world is a mixture of a sodium calcium silicate. The colors of the glass are obtained according to the following palette: blue: copper oxide (CuO) and sometimes even iron. The darker blues may be based on copper but cobalt is added. Green is obtained from the reduction of ferrous oxide (FeO). Transparent amber is obtained from ferric iron (oxidized), amethyst or purple is obtained from manganese, and red opaque from a suspension of cuprous oxide in its vitreous part with high lead content. The opaque white is due to a suspension of tin oxide, and yellow from antimony compounds. Glass has many uses such as in containers, stained glass, personal adornments, lighting systems, pharmaceuticals, etc. In total, there are 75000 known ways of making glass, which makes impossible to establish a method, a system, and a chronology for manufacturing it [10].

The glass can be recycled indefinitely, not always it should go to the garbage. For example, a broken glass or a bottle whose content have finished. Although it may not seem so, due to the overabundance of plastic products, glass forms an important part of the garbage generated in cities. Glass takes up a lot of space and is heavy, so it takes more energy to transport and treat this waste. The glass recycling process requires special furnaces that melt the glass again, but before that a fine selection is required. In glass recycling plants, the glass is treated, separated by chemical composition, and then by color. Not all recycling plants are prepared for all types of chemical compositions, nor are they prepared to recycle all colors, as each type of glass must be recycled separately, otherwise it can ruin an entire batch. The glass retains its color after recycling, that is why they are separated, this implies a great saving at the time of coloring a molten glass from zero. The most common are transparent, green, and brown. There are also different types of glass. For example, bottles have a special composition, without lead, or other aggregates that are usually incorporated into window glass, car windshields, or even glass. Therefore, they must always be separated. Once separated, the glass is treated and washed to remove all types of impurities, such as grease, paper, etc. Then, it is smashed until it turns into small pieces, which are passed by magnets to remove any type of metal that may remain.

2.3. Bone

It comes from the term ossum which refers to all the hard and rigid pieces that form the skeleton of vertebrates [11]. It is found that bovine bone has certain percentages in its chemical composition which are distributed as follows: 30% organic matter, 45% inorganic matter and 25% water. The organic matter present is in the form of osteoblasts, collagen, osteonine, among other components that are known to be destroyed by disintegration or calcination. For this reason, no emphasis will be placed on them. Inorganic materials are present in a 45% such as: hydriapatite matrices [$Ca_3(PO_4)_2$ $(OH)_2$] and calcium carbonate. Smaller quantities of sulfates, fluorides, and magnesium hydroxide are also present. On the other hand, it analyzed the thermal diffusivity of several materials among them the bovine bone in different degrees of pulverization, explaining the thermal behavior in each of the components. This

showed that it could withstand in the best of the cases up to 1500 degrees centigrade, data very relevant to consider.

2.4. Coconut shell

The coconut tree is a plant that belongs to the palm family and to the class of monocotyledons. Its scientific name is cocos nucifera and its common name is coconut. The most outstanding varieties are the tall and dwarf coconut trees, but sixty varieties have been recognized. However, the powder obtained by crushing the shells has been recommended as a carrier agent of molasses. Coconut shells can be used to make various utensils such as bowls, cups, spoons and ladles, smoking pipes, ashtrays, vases, boxes, and toys. If used as fuel, the resulting ash is high in potash (30 to 52 percent). The shell also yields a high-quality carbon used in chemical filters. The "flour" resulting from grinding the shell is used in the manufacture of plastics to luster molded items and improve moisture resistance.

The fruit of the coconut tree is a drupa monosperma. It consists of an exocarp, mesocarp, endosperm, coconut water and endocarp. The whole fruit can weigh up to 1 kg to 1.5 kg in its mature stage and the approximate proportions of its parts are as follows: mesocarp 35%, endocarp 12%, endosperm 28%, and coconut water 25%.

The endocarp is the hard-brown layer, which in some cases serves as fuel, due to its high lignin content. This dry material is composed mainly of cellulose, hemicellulose and lignin, in such proportions that it resembles a hardwood. Cellulose is a homopolysaccharide and the most abundant organic matter in the world. Since 1889, it has been an option in the manufacture of fibers intended to replace natural silk. This application had a time, until synthesized polymers such as polyester and different types of polyamides were used instead of natural fibers. Lignin is the second most abundant biological material in the world. It is a polymer made up of phenylpropane units. This substance prevents the entry of destructive enzymes through the cell wall. Lignin is considered one of the molecules responsible for making wood harder.

The chemical composition of the coconut endocarp, as in any other fiber or bark, depends on different factors such as the age of the plant, the specific climatic conditions of the area where the plant was grown, and the degradation process that has occurred until harvesting or analysis [12].

3. Methodology

A comparative analysis is carried out between the theoretical thermal conductivities of quartz, glass, bone and coconut shell materials, and the experimental results obtained by means of thermal conductivity tests for granular materials in the laboratory.

In the first phase, information will be collected to know the thermal conductivity of each of the materials that have been theoretically reported in documents, papers, and books. In the second phase, the materials are pulverized, then the materials are passed through a sieve number 40 and then 30, respectively, to obtain the final sample to be introduced into the test specimen, and finally, find the values experimentally through the thermal conductivity test bench for granular materials as a show the Figure 1.



Figure 1. Thermal conductivity test bench for granular materials.

The thermal conductivity test bench for granulated materials works by measuring a physical property that is the temperature conduction through a material, with which depending on the value thrown we

can determine if a material is conduits or insulator, this is very helpful when time to make designs and use materials because depending on their application they can be used and characterized according to their physical property present in any material.

4. Results

When developing the different tests, the first step was the pulverization of the material so that it fulfills the function of being granulated and suitable for carrying out thermal conductivity tests, followed by micrographs of each sample, and finally the results were found on the test bench for granular materials.

The following is the formula for thermal conductivity as in Equation (1) that is used by the thermal conductivity test bench for granulated materials.

$$k = \frac{VILn(\frac{r_2}{r_1})}{A(T_2 - T_1)}. \quad (1)$$

Where k is the thermal conductivity coefficient. V is voltage, I is the intensity, A is the normal area to heat flow, (T2-T1) is the temperature gradient.

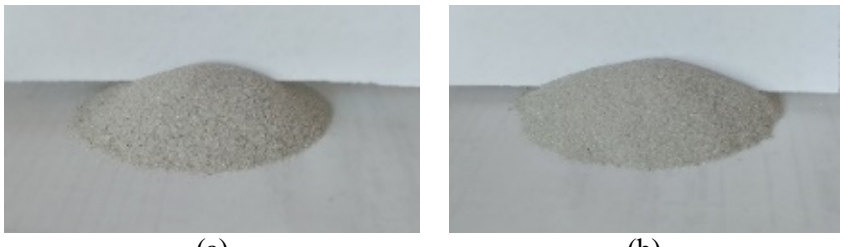
4.1. Pulverization of materials

In order to carry out the conductivity tests, the samples must be prepared. To do this, it is necessary to pulverize by means of mechanical or electrical mills in order to reduce the grain size and to sieve under the ASTM E11 – 17 [13] standard with a Granotest sieve with 40 and 30 mesh as shown in Figure 2.



Figure 2. Use of the Granotest sieve 40 and 30 mesh.

Obtaining in this way, materials with low grain size and in granular or powder state, as shown in Figure 3, where the Figure 3(a) show the Quartz and the Figure 3(b) show the Glass, for performing thermal conductivity tests.



(a) (b)

Figure 3. Screened samples: (a) Quartz, (b) Glass.

4.2. Micrographs

The micrographs were taken under an Optika B-157ALC microscope, thus observing the grain size of each of the granular materials, as a show the Figure 4, where the Figure 4(a) show the Quartz, the Figure 4(b) show the Glass, the Figure 4(c) show the Bone and the Figure 4(d) show the coconut shell.

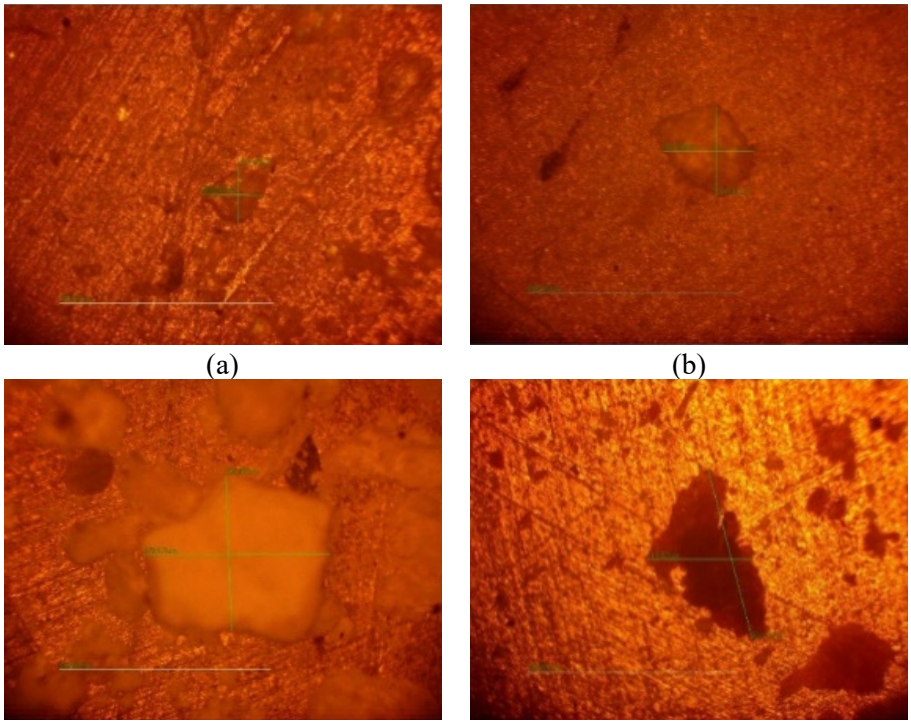


Figure 4. Micrographs: (a) quartz, (b) glass, (c) bone, and (d) coconut shell.

4.3. Thermal conductivity test

The results of the thermal conductivity of each material are shown below in the Table 1 show the conductivity of quartz., Table 2 show the conductivity of glass, Table 3 show the thermal conductivity of bone, and Table 4 show the conductivity of coconut shell.

Table 1. Experimental thermal conductivity of quartz.

Time (min)	K (w/k*m)
0	45.840
10	1.490
20	1.320
30	1.590
40	1.560
50	1.550

Table 2. Experimental thermal conductivity of glass.

Time (min)	K (w/k*m)
0	15.090
10	2.320
20	2.710
30	3.140
40	3.050
50	3.210

Table 3. Experimental thermal conductivity of bone.

Time (min)	K (w/k*m)
0	47.880
10	0.890
20	1.040
30	1.250
40	1.330
50	1.310

Table 4. Experimental thermal conductivity of coconut shell.

Time (min)	K (w/k*m)
0	4.970
10	2.210
20	2.370
30	2.760
40	2.720
50	0.620

4.4. Comparative between theoretical and experimental thermal conductivities

Table 5 shows a comparison of the theoretical and experimental thermal conductivities of each material.

Table 5. Thermal conductivity of granular materials [14].

Material	Thermal conductivity K (w/k*m)	
	Theoretical value	Experimental value
Quartz	1.200 - 1.400	1.550
Glass	0.080	3.210
Bone powder	0.011	1.310
Coconut shell	0.460	0.620

5. Conclusions

In this work, the experimental thermal conductivities were obtained as the physical property of the elements such as quartz, glass, bone powder and coconut shell, which were carried out with a manual crushing process that reaches a 30-mesh screen to measure conductivity in the thermal conductivity test bench for granular materials. When comparing these values with the theoretical data, it is observed that there is an approximation in the value of the thermal conductivity of quartz and coconut shell, but there is a significant difference in glass and bone dust; It is believed that it depends on factors such as the characteristics of the materials, the physical properties and the grain sizes that affect the experimental data and the classification of the materials in thermal conductors or insulators in comparison with the theoretical data, values were found that do not allow classify the material according to what is recorded in theory, which opens up future research that will allow each material to be characterized in a more appropriate way with respect to its physical and mechanical properties.

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